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## Implementation of technical knowledge into the early design phases

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### *3. Implementation of technical knowledge into the early design phases*

 *BY MADSDINES PETERSEN*

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**Keywords:** Architecture, Design Process, Sustainability, Simulations, Building Information Modeling

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Project/chapter	Theory input	Methodology	Epistemology
Implementation of technical knowledge into the early design phases	Design theory Architectural theory Engineering energy theory	Interviews Action Research Experiments	Emperical – Analytical Pragmatism

## ***Introduction:***

Discussions about sustainability in architecture have been present since the seventies (Williamson, Radford & Bennetts 2003) and today architects are becoming increasingly aware of sustainability in their work and also in communicating these issues, as it is for example seen through exhibitions (Juul Holm, Kjeldsen 2009). In Denmark the discussion about sustainability is mostly focused on the energy consumption during operation, which is also reflected in the building regulations (Erhvervs- og byggestyrelsen ) and with the increasing interest in developing passive houses in Denmark where different pilot projects are currently seen. It is within this context that my approach to sustainable architecture is located. This increased focus on energy consumption requires the architect or design team to be able to utilize knowledge about relations between the architectural form and sustainable issues – basically meaning recognizing and using the fact that the technical issues have an impact on the architectural form and using that knowledge to help develop the ideas as seen in the Integrated Design Process (Knudstrup 2004). Research shows that it is important to address such issues early in the design process as this is where the impact of decisions are biggest (Chaszar, Kienzl & Stoller 2006, Neuckermans 1992), but it is also seen that the use of the different assessments, especially digital tools are mostly limited to the later stages of the design process and that the tools developed to make these simulations are difficult to use in earlier stages, making it more difficult for architects to utilize them in what could be described, as the crucial early stages of the design process where the initial and intuitive ideas based on previous experiences needs to be tested against the constraints of the brief and legislation. This problem is the point of departure for this PhD that draws on the developments in performance based simulations and Building Information Modeling (BIM) as

well as knowledge about the design process. It focuses on how knowledge about the design process and the parameters that affects them in relation with new digital tools can help the design team to address issues about especially energy consumption during the early stages of the design process as research show is important (Chaszar, Kienzl & Stoller 2006, Neuckermans 1992).

## ***Research question:***

How can knowledge about the design process used in praxis and the Integrated Design Process (IDP) be used to help architects address issues about energy consumption during operation of buildings as a part of the early conceptual parts of the design process through the utilization of digital tools?

This question can then be split into three sub questions that address different perspectives of the main question as it is suggested by Andrews (Andrews 2003).

1. How are tools, currently used to address these issues in relation to the design process?
2. How do architectural offices considered as being among the leaders within sustainable architecture structure their design process with specific focus on how they address issues related to energy consumption during operation?
3. What are the possibilities for implementing knowledge about parameters affecting the energy consumption in the design process?

The research points towards gaining knowledge about how experiences from the IDP at Aalborg University can be used in relation with praxis based design process to develop the

design at an early stage of the design process in terms of the energy consumption during operation. It is especially focused on how to implement it in a practical context. Furthermore it explores how digital tools, with a focus on BIM, can help to support the implementation of knowledge at such an early point in the design process in order to help inform the design team.

### **Methods:**

As seen in the research question the main focus is on how architects address issues about sustainability in the design process today. The PhD attempts to address these questions from the architects' point of view and understand their design process in order to relate it to the IDP set in an educational context. In order to work with these questions and gain insight to the practitioners view upon these issues it has been chosen to work with some examples where these issues are seen from the practitioners' point of view through interviews (Kvale 1994) with different architects, as well as literary review of the subject. These interviews have the form of conversations with the architects in order to gain knowledge about how they work with these issues and what their experiences are. They are designed as semi structured interviews (Kvale 1994) where the aim, as mentioned above, is to gain an understanding of how architects experience these issues in their work. This is then related to the experiences from the educational context at Architecture, Design & Media Technology that forms the starting point for my understanding of how a design process can be structured. The interviews revolve around three main questions that have a primary relation to the first and second research sub question.

1. How do they approach the design process in a competition?
2. How is the work with sustainable issues affecting this and what are their experiences?
3. What barriers do they encounter with them during the design process and how do they work their way around them?

As one can see the questions aim at giving an understanding of how sustainability is affecting the design process as well as what problems they may encounter during their design process in relation to their work with sustainable issues. The setup for the interviews is a conversational setting where the architect through the conversation is encouraged to reflect upon their work through questions – a setup where the knowledge can be drawn from the conversation (Kvale 1994) where the literary review of previous research into the different theoretical fields creates the framework for the analysis. The interviews are seen as examples that are focused on discussing how architects approach issues about sustainability in the early conceptual parts of the design process and through that discuss the possibility of implementing knowledge from the experiences at Architecture, Design & Media Technology, Aalborg University, in order to give the architects tools to deal with sustainable issues at such early conceptual stages.

Through the interviews outlined above an initial understanding of how architects work in this early conceptual development of the design process is gained and forms the basis of the part of the research that is conducted as action research (Reason, Bradbury 2001) where the data is collected through observations during the design process and the use of writing “diaries” the design process and the models and notes made as part of the project. In order to work with this

it is important to have knowledge about how they approach the design process and how they work. Using action research as a method here is chosen because knowledge about the work they do in the office is needed as well as knowledge about what can be done to change some of their procedures is needed. The work here is made in relation to an architectural competition where the knowledge gained from the IDP (Knudstrup 2004) is used in order to see how it can help to inform the design process.

Besides case studies, interviews and action research small experiments (Groat, Wang 2002) will be made in order to study how different programs can be used and possible how knowledge about sustainable issues can be implemented directly into modelling programs. This part is related to the third sub-question and is seen as a parallel to the main subject

and serves as a way to gain knowledge about how different programs might be used in a design process.

As one can see the main body of the research is based on a qualitative approach with interviews and action research in order to understand the different issues from the architect's point of view, though, with small experiments to support it. Choosing this inherently qualitative approach is due to the focus on implementing knowledge to existing design process. In order to do that I have chosen to address these issues in a practical context and relate that practical context to the theoretical context due to the aim of gaining a better understanding of how knowledge from the two contexts can be used to move them closer together and help inform each other – each of them giving a different perspective of the question.

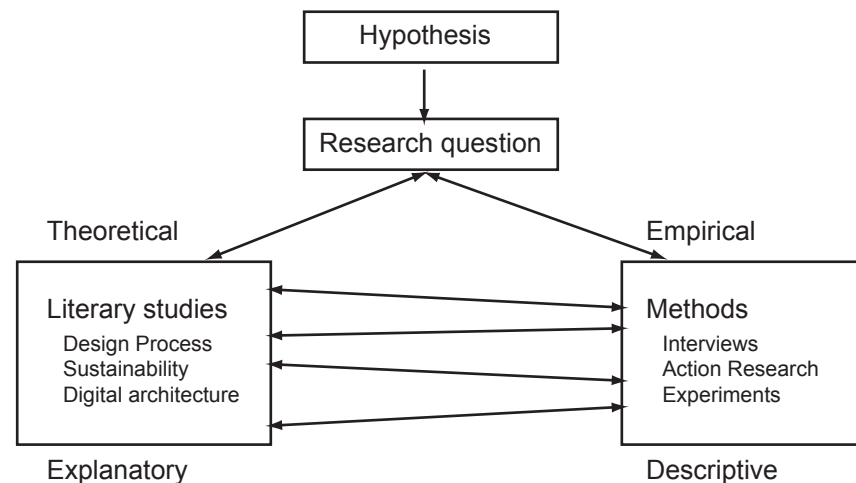


Figure 1. Diagram outlining the methodologies and the design of present research

## *Theoretical frame*

As indicated above, present PhD is located in a diverse field of theories however with a focus on the design process and through that how architects work in the design process with sustainable issues in digital tools to support this work. Even though this is the primary theoretical focus it is touching upon engineering theory related to energy consumption and its relations to architecture as well as systems theory which is also related to the design process and the understanding of relations between different parameters that affect the design process and design theory related to the application of digital tools with specific focus on BIM.

With the theoretical framework being focused on the design process this will be the starting point here, where the IDP (Knudstrup 2004) used at Architecture, Design & Media Technology is the point of departure and is framed within a larger discussion about the design process as seen in figure 2 and described more thoroughly below.

At Architecture & Design, Aalborg University, the design process is focused on the Integrated Design Process (IDP) where technical knowledge is implemented in the architectural design process in order to let it inform the design process and through that create a hybrid design process located within an educational context (Knudstrup 2004), though it is based on the approach used in architectural offices. This means that it attempts to describe a design process where technical issues related to sustainable concerns are integrated and related to traditional architectural virtues in order to let them inform each other on a more conscious level than might traditionally be seen. This is especially evident in relation to the students' work with environmentally sustainable architecture where different calculation and simulation tools are used during the design process. A diagrammatic representation of it is seen in figure 3.

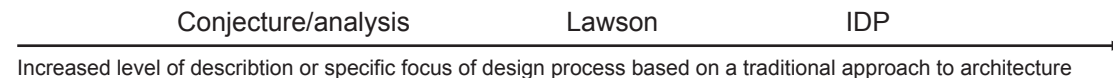


Figure 2. Placing different descriptions of the design process in relation to their specific focus and level of description.

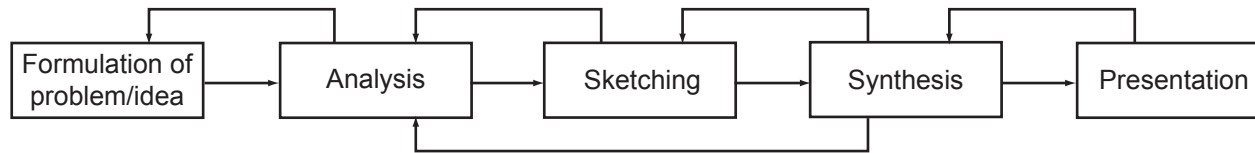
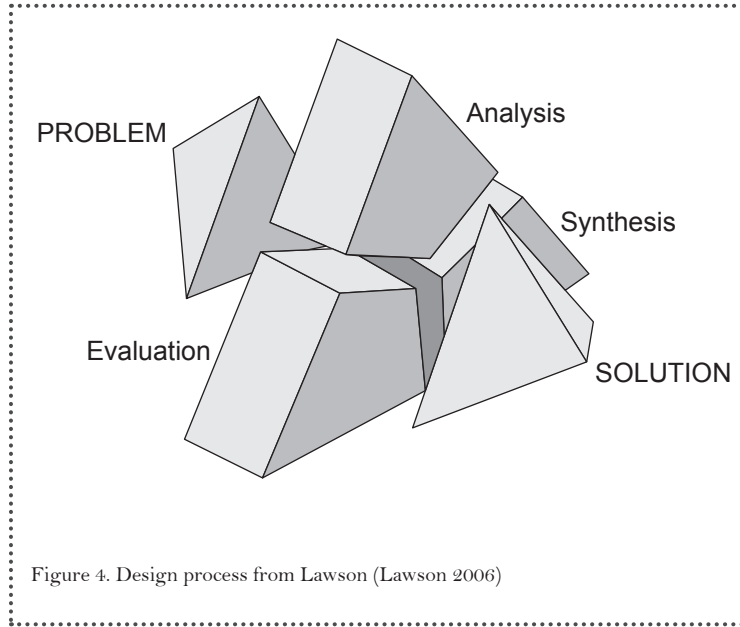


Figure 3. Integrated Design Process (Knudstrup 2004)

Research into the design process started initially during the sixties and seventies and has developed from there. This initial research points towards architects working through a conjecture/analysis model where the knowledge from previous experience is used to pre-structure the problem (Hillier, Musgrove & O'Sullivan 1972). Furthermore it showed that architects worked from a point of departure where they had a simple starting point as for example a feature in the landscape and used that as a driver of the design process (Darke 1979). This opposed some of the theoretical developments where theoreticians argued for a more scientific approach to the design process where the problem was analysed and sub-divided into sub-problems that could then be solved and re-assembled into a solution as it is for example described by Alexander (Alexander 1994). Today this line of thought still exists and is seen in different

variations of integrated design processes as for example IEA's task 23 (Löhnert, Dalkowski & Sutter 2003). It describes that one needs to analyse the problem, sub-divide and solve the problems before re-assembling the parts. But it does not take into account that design problems are often wicked, ill-defined problems with a huge complexity (Cross 1982, Cross 2006). A discussion also taken by other researchers describing the design process (Lawson 1980, Lawson 2006). Lawson's description of the design process can be seen in figure 4 where it is seen that it has very little direction. It can be seen from different stages but all of them inform each other making it difficult to break into discrete parts. Similar to this Schön describes how architects work with reflection in action constantly analysing the sketches investigating the results through their knowledge, almost having conversations with their sketches (Schön 1995).





If one then focuses on working with sustainable architecture, which here is focused primarily on energy consumption during operation, as a point of departure for the studies it becomes interesting to investigate the relations between them. But it is important to note here that the discussion is much broader than that and is also based in a more philosophical sphere (Williamson, Radford & Bennetts 2003) not discussed here. However looking at what has been published about sustainable architecture within the past decades it is evident that there already is knowledge about how this should be done and practical experiences with it (Olgyay 1992, Brown, Dekay 2001, Yeang 1999). It is for example outlined in Olgyay's publication where a methodology for what he refers to as bioclimatic design is outlined as shown in figure 5. Of course all of the terms used in this figure must be related to the architectural developments and ideas.

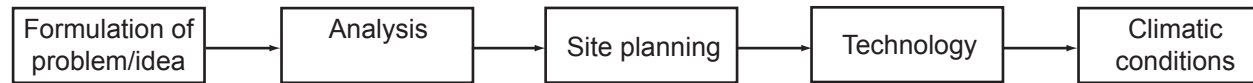


Figure 5. Diagram representing Olgyay's steps in bio climatic architecture

Within this approach there is a clear hierarchy in what needs to be done first. If this is set in a more contemporary context it is seen that considerations are made in relation to addressing these issues from an engineering point of view where the use of digital tools to support such a design process, but rarely in relation to a buildings connection with a site as seen in vernacular architecture (Thomas, Garnham 2007) or as some architecture, despite the fact it is not considered to be located within the term sustainable architecture, does (Steele 2005). Here it is the way the existing tools are used and how the results should be interpreted that are in focus (Chaszar, Kienzl & Stoller 2006). With this approach knowledge about both the programs employed is needed as well as the parameters that are relevant at a given stage is needed. Focusing solely on these issues can break the design process down to parameters analysed and solved individually and from there a solution is derived (Alexander 1994). This points in a direction where a systematic thinking is in focus and where the different parts can be treated individually. This is an important point and when working with complex problems as is seen with

energy consumption in buildings. However as Alexander describes himself complex problems like that quickly becomes impossible to deal with because of amount of relations in it (Alexander 1994). This is probably better explained by Lawson in his example with a horse carriage and why its wheels are mounted as they are (Lawson 2006) – an example that shows the possible complexity of understanding how the different parameters in design affects the final design of an object.

In relation to this it is necessary to study how the design process today is supported by a variety of digital tools with a strong focus on how, especially; environmental issues are addressed during the design process pointing towards the use of different kinds of calculation and simulation programs. The tools used today also points towards the future. Today the design process is heavily influenced by the use of digital tools in the design process ranging from tools for generation, animation, performance-based design and materialization (Oxman 2006, Kolarevic 2003). The before mentioned influences are active in the design process where active in this

context means that the tools are used to generate solutions from an input from the architect without the architect takes part in the actual form generation. Another way to use digital tools is a more passive approach where the digital tools are substitutes for analogue tools as it is seen in relation to the use of CAD drawings today where the architect still has full control over the design process. This has had a great influence on the design process and the implementation of these drawing practices has caused discussions about the architects position (Schodek 2004). This only serves to show the diversity of directions within the discussions about digital tools in architecture and in the following, the more specific aim in relation to present PhD.

In a more general practical context the focus is on BIM which basically is an approach that allows for easier interoperability between different professions and the programs they use through agreements on file formats and where all information is gathered in a single model making it easier and more efficient to work as well as reducing the chance of having drawings from the different consultants that are not updated to match each other. Besides that the approach is based on 3d models that includes all this information instead of 2d representations as has traditionally been used (Eastman 2008). This is today seen as crucial for the developments in the building industry both in terms of possibilities in the design as well as the possibilities for optimizing the link to manufacturing. These are the possible benefits as well as the implementation of material properties, component definitions etc. makes it possible to link more directly to different simulations programs (Schodek 2004, Eastman 2008) which in the end means that it should be possible to get answers quicker than in a traditional process where multiple models has to be made as well as translations from 2d to 3d drawings or manual inputs to calculations programs. Current research show that there are problems with this and that the work flow currently is not as fluent as one could hope it to be (Schmitt

2004, Penttilä 2007). This can also be seen in relation to the lack of tools that allows for the architects and engineers to use them throughout the process instead of at certain steps making it a difficult field to navigate in (Krygiel, Nies 2008).

As a last note it is, however, important to note that these are not new issues to address. As mentioned previously many of the parameters that affect the energy consumption of the buildings we design are seen in vernacular architecture and are issues that are addressed anyway – though they might be addressed solely from a functional or aesthetical point of view. To some extent it can be said to underline the importance of the measurable supporting the immeasurable (Kahn 2003). Or as others have expressed that the discussions about sustainable architecture is a current trend and that it should not overshadow what architecture is about (Harries 1997). In relation to the outcome of present research this means that it is aiming for studying how knowledge already present can be integrated in the design process through the use of digital 3d object based tools, without removing the focus from the aesthetical expression of the architecture. It is not the aim to develop a general methodology. It is to understand how a better understanding of the design process can help to improve and integrate the work with sustainable architecture further into the design process.

### *Theories of science*

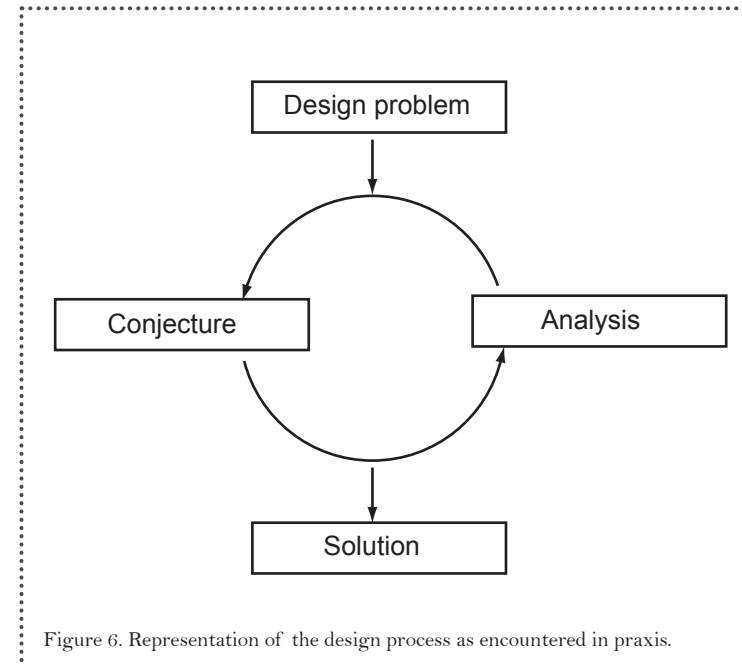
The outcome of present PhD is how existing knowledge about the IDP, informed by studies of how architects think and work, can help to inform architects about the energy consumption during the early stages of the design process and how existing digital tools can help to provide and support such knowledge, thus creating a more common ground between the different professions involved in the design

process. It is the relations between the architectural form and the energy consumption there is in focus here as well as how this knowledge is implemented in the design process and how it can help to inform the design process and the final design of the building. The contribution lies in:

1. Expanding the field of knowledge about how architects approach the design process, especially now where the demands are increasing, and through that knowledge about how this can help architects to assess environmental issues from the early conceptual stages of the design process.
2. Expanding the field of knowledge about what implications the use of simulation programs can have on the design process.

With the design process in praxis described as a conjecture/analysis process where the architect from previous experiences generate one or several solutions as a starting point it is seen that it differs profoundly from the analysis/synthesis often described in teaching situations and other integrated design process (Trebilcock 2009). However my claim is that the two approaches can help to inform each other. Where the conjecture/analysis is based on using previous knowledge to start the design process through conjecturing (Hillier, Musgrove & O'Sullivan 1972, Darke 1979, Trebilcock 2009) the analysis/synthesis takes a more analytical approach identifying different parameters that are of importance for the solution to the given problem in the design process, but this is difficult because design problems are wicked and ill-defined (Cross 1982, Cross 2006) and the full scale of the problem is impossible to describe or analyze. However architects do analyze their work through the process and are using different parameters to do it. So if these parameters are a part of the first thoughts they will be an integrated part of the solution if the knowledge about how to address them and

use them is also present. Then the sketching phase is used as a dialogue between analyses and sketches where they inform each other throughout the process where the architect reflects upon the work as the sketching progresses (Schön 1995) as shown in figure 6.



Therefore the knowledge about technical issues and their possible impact on the design is becoming more important as the complexity grows. For the architect it becomes important to be able to integrate this explicitly in the design process in order to let it inform the design process and through that strengthen the link between the technical issues that is a part of the design process and the architectural form and expression.

Now one of the interesting questions in relation to this is how the increasing focus on BIM in the design process can be seen and understood in relation to knowledge about the design process and how this knowledge possibly can be used to approach some of the problems in utilizing BIM in the early stages of the design process (Schmitt 2004, Penttilä 2007). This is interesting because BIM is seen as the future in architecture and currently are used in various projects in order to streamline the design process (Schodek 2004, Eastman 2008). It is important to address the different issues at the right time during the design process. For example basic parameters like orientation, window openings and basic geometry of the building are crucial to evaluate both from an architectural and technical point of view from the beginning whereas for example ventilation systems can be addressed separately (Chaszar, Kienzl & Stoller 2006). Though one still has to be aware of that they need to be there. So even though the use of BIM can solve problems about interoperability it so far does not solve problems in the early design process. At least that is what research shows (Schmitt 2004, Penttilä 2007) and this is also confirmed by the preliminary analysis of the interviews, which have not been published yet, made with architects. In fact these interviews show that they don't use BIM tools during the very early stages of the design process. In terms of outcome for present research this means that the understanding we have of the architects design process both from research and previous experiences needs to be utilized. One cannot force a solution upon them, but have to work with how the knowledge from, in this case, the IDP can be used in their process and explores how an evidence based process can help to inform an experience based design process. So the question becomes how the evidence that one can find through using different simulation programs can be used in a design process that is traditionally experience based without relying on guessing different solutions, but by utilizing knowledge that is already

present through a focus on identifying key parameters in the design process.

There exists a variety of guides within this field all focusing on how to utilize the environment in which one is building (Olgyay 1992, Brown, Dekay 2001, Yeang 1999). Furthermore a variety of schemes are today available in order to help architects and design teams to address the different issues and in the end rate the building in terms of how sustainable it is (LEED 2009, BREEAM 2009). Again the question is to use the knowledge in relation to the design process and the digital tools used to address the different issues. Here the schemes are of little use so they are not taken into further consideration. What is of importance here is to be able to locate the different parameters of interest in the problem and then describe and assess them in relation to the aims one have (Chaszar, Kienzl & Stoller 2006). This is also what is done in the IDP where both architectural and technical demands are outlined (Knudstrup 2004). Furthermore all the different issues that have an impact on the solution in relation to designing architecture are more or less impossible to list (Cross 2006). However the parameters addressed related to the energy consumption are often perfectly integrated in the design process as seen in vernacular architecture (Williamson, Radford & Bennetts 2003, Thomas, Garnham 2007, Steele 2005) however they might not be addressed from an environmental point of view even though these issues are basic within architecture (Reinmuth 2010).

Today there is a variety of research dealing with the issue of using computers to implement concerns about sustainable issue especially with a focus on energy consumption. There are of course the basic ones dealing with checklists (Synnefa, Karlessi & Santamouris 2008, Hyde et al. 2007) as it was also mentioned before to approaches focusing on generative principles to generate a range of solutions to work with in building scale and where the interaction between computer

and architect is important (Grobman, Yezioro & Capeluto 2008) and finally to the more technical approach where comfort criteria's, energy consumption and basic geometry is defined and from that a range of spaces are created that can then be assembled into a building as seen in IDBuild (Petersen 2008). However these are developed in a research environment and are rarely used in praxis. Though the IDbuild has been used with architects research shows that architects do not necessarily find it useful in the design process (Petersen 2008). What is seen in relation to the last two approaches is for using the computer as a colleague that helps one in the design process (Negroponte 1970), though, this is still an issue where architects are worried about their influence on the design process (Yu-Tung 2007, Xiyu, Mingxi & Frazer 2005).

All of the above on some level is pointing towards understanding the design process and the approach to it as something that creates a solution space that we as architects can navigate in. With the conjecture being a implicit solutions space defined primarily by previous knowledge whereas an analysis points towards a more explicitly defined space.

It is within these fields of sustainability, design process and digital tools with a focus on BIM where I see the contribution of present research. It aims at developing knowledge about how these three fields can interact to allow a focus on architectural qualities and through that suggests how architects can address the relations between sustainable issues and traditional architectural issues during the early design stages. Working with this mainly through qualitative interviews and action research allows for working in the context and with some of the people that have to work with these issues on a daily basis and through that get an understanding of how the architect see these issues getting experiences with how these issues can be addressed in the present approach to the design process with the possible

problems and conflicts that can be encountered in it. Through it, it becomes possible to be engaged in the work in a way that the study environment cannot give and that small experimental projects with a specific focus on certain issues can have difficulties to address. Of course the approach also calls of an amount of uncertainty. As a researcher the control with the process will be diminished and the outcome and possibilities for adjustments in the process also diminished. However doing the research this ways allows for working and getting and improved understanding of what is required in order to make these things work in an actual design process. Furthermore the variety of methods used in the research ranging from literary studies over interviews and action research to small experiments allows a validation of the data through different perspectives.



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